E/CONF.39/A/38
29 Sept.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.2

South Africa

MECHANICAL EQUIPMENT USED IN THE MINES OPERATED BY TRANSVAAL GOLD MINING ESTATES, LIMITED, PILGRIMS REST DISTRICT, EASTERN TRANSVAAL, REPUBLIC OF SOUTH AFRICA

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MECHANICAL EQUIPMENT USED IN THE MINES OPERATED BY TRANSVAAL GOLD MINING ESTATES, LIMITED, PILGRIMS REST DISTRICT, EASTERN TRANSVAAL, REPUBLIC OF SOUTH AFRICA.

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1. INTRODUCTION

1(a) In order to appreciate the types of mechanical equipment used in the small mines operated by the Transvaal Gold Mining Estates, Limited, it is necessary to give a background of information on the occurrence and geology of the ore-bodies in the area and a general description of the mine layouts planned for the use of mechanical equipment.

1(b) The mines operated by the company are scattered over an area of some 200 square miles in the Drakensberg Mountains of the Eastern Transvaal. The country is heavily dissected with mountain ranges reaching heights of 7,500 feet. Deep valleys and ravines reaching a depth of over 2,500 feet are caused by river erosion, thus exposing the interbedded gold carrying reefs. The mountain ranges run roughly north to south, with the formation dipping gently to the west at 4-6°.

1(c) The mines have been worked continuously since 1872. Although rich in places, they are, generally speaking, medium to low grade and with low percentage payability, with many mining difficulties caused by faulting, oxidised ground and waterlogged conditions. The presence of copper associated with the gold and, in places, arsenic causes metallurgical difficulties.

1(d) Due to these difficulties and the scattered nature of the ore bodies, the mines for the most part have been fairly low profit earners, and the last 20 years of the company's life have been a continuous struggle for survival. These conditions have dictated the mining policy. With limited ore reserves and marginal profits, capital expenditure has had to be limited. A high degree of mechanisation has not always been advisable, due to the generally very narrow reefs. In all, some thirty individual mines have been operated, with the ore milled in six separate plants strategically positioned over the 40 miles of strike of the property. There is a wide range in the size of the mines.

2. GEOLOGY OF THE AREA

2(a) The Pilgrim's Rest Goldfields occur in the Transvaal System which is probably early Proterozoic and forms the middle portion of a group of formations that are of later Precambrian age. These formations overlie the Basement Granites of archaean age.

2(b) The interbedded reefs occur mainly in the Dolomite Series which reaches a width of over 3,000 feet. The reefs dip gently to the west conformably with the strata. Some ten different super-imposed reefs have been worked in the Series. The main horizons on which the majority of the mining has been done are the Lower Theta, Beta, Portuguese and Glynn's Reefs. The reefs for the most part are narrow in width with erratic payability. Similar reefs are found above and below the dolomite in the Pretoria and Black Reef Series. Leaders have been found dipping across the strata. Due to the extensive river erosion which generally runs parallel to the strike of the country, the rock formations new surface are heavily weathered and decomposed, with the reef outcrops oxidised. At varying distances from the outcrop the dolomite becomes extremely hard and cherty and the reefs pyritic. Slumping and solution faulting are common.

FIGURE I shows a typical columnar section through the rock formations near Pilgrim's Rest.

3. GENERAL DESCRIPTION OF THE MINES

3(a) The erratic nature of the gold distribution and the average low percentage payability, which is less than 5% for the area in general, make long term planning of mine layouts difficult. In most cases mines are opened up from payable outcrops by adits into the hillsides or by inclines sunk on the dip of the reef. Workings follow the payability, and prospecting is done by underground development. Diamond drilling from surface for prospecting the dolomitic reefs has not proved reliable due to the hardness and broken nature of the dolomite, and the soft oxidised or friable pyritic reefs. Payability has extended long distances underground from the original outcrop, for example, at Glynn's Lydenburg mine workings extend over 20,000 feet into the mountains.

3(b) The reefs in general dip away from the outcrop giving rise to underground water problems. The dolomite in some areas carries large quantities of water, and amounts in excess of 6 million gallons per day have been encountered in headings underground. Low level drainage drives are developed when possible for dewatering the mines. In one instance a drive of nearly 15,000 feet tapped 13 million gallons per day.

3(c) In the mountainous areas a number of super-imposed payable reef bodies occur in places. The scattered payability and terrain are the main consideration in determining the method of surface ore transport to the mills. Wide use has been made of various types of rope haulages.

3(d) Many systems of stoping have been used with varying degrees of mechanisation. Limiting factors are the irregularities and the narrow reef widths. The values are usually such that a clean uncontaminated product must be sent to the mill.

4. STOPING

4(a) For interbedded consistent hard rock reefs dipping between 0^{o} and 20^{o} with reef widths over 20 inches, cleaning by scraping has proved most efficient. For reasonable working conditions stope widths should not be less than 28 inches, while widths in

excess of this can be handled satisfactorily with scrapers. The stope width is determined by the reef width and the position of suitable parting planes in the rock strata. The length of the scraper pull is determined by payability and the production rate required.

4(b) A typical stope on sulphide reef is as follows:- The length of scraper pull on face is 300 feet. The stoping width is 30 inches with a reef width of 20 inches. 100 face holes are drilled per shift by 2 machine crews of 2 men each. The depth of hole is 42 inches. The face is blasted once per 24 hours with cleaning on the opposite shift. 200 square fathoms are broken per month with a production of 60 tons per shift handled to surface. The face advance is 24 feet per month. The method of support is 4 feet square 4-pointer waste filled timber cribs, with reef scatterpile for protection from blast scatter. 15 h.P. scraper hoists with a rope speed of 200 feet per minute pull a scraper shovel with a capacity of 0.4 tons. The length of the scraper pull can be shortened for increased production with closer hole spacing.

4(c) With narrower reefs it has been found that some type of resue stoping method is advantageous. Straight stoping of narrow reefs causes excessive dilution of broken ore values, and higher tonnages for transport over the long distances to the mill. With this method of stoping, scrapers have been found to be ineffective as excessive quantities of waste are removed, and control of grade is difficult. An effective stoping system is the herringbone, with strike tracks varying from 24 to 40 feet apart on dip. Track height is obtained by footwall lifting, and the tracks are kept close to the face. Care is required with track direction to avoid convergence, as strike determination on flat dips is difficult. Survey direction lines are usually carried. Stope cars of .5 ton capacity are handloaded at the face, and handtrammed to the centre incline rope haulage or scraper gulley. In the latter case end tipping cars are used on the strike tracks fitted with gooseneck rails at the tipping point. The distance of strike tram is determined by hanging-wall conditions,and is inefficient at distances in excess of 300 feet. In resue stoping waste over or under cuts are made and this product packed in the stope. Reef is lifted when convenient, and production from a pair of faces can be fairly evenly maintained. Should reef be broken inadvertently during the waste cut, it is hand-sorted and removed before the next blast. Reef ledges of 10-12 feet are cut before being lifted.

4(d) With a semi-oxidised ore in hard dolomite country rock as at Vaalhoek mine, a short cycle over cut resue system was most effective. Each daily waste blast is removed to the waste fill by handlashing. Following this operation, the reef is mined as far as possible by a crew using pneumatic picks. On completion of the waste removal, the scraper commences reef removal starting from the top. The sweeping crew then follows the scraper down until all reef is removed and the stope completely swept. At this stage the face is ready for the machine crew to drill the holes for the waste cut. The cycle is completed in eight hours for a face length of 250 feet. With a reef width of 9 inches, a mill width of 15 inches is expected. Stopes valued at 120 inch-dwt. produce a product to the mill of approximately 7 dwt. Monthly face advances of 12-15 feet were

obtained with a daily production of 18 tons of reef per face.

4(e) Under soft ground conditions, mechanical cleaning by scrapers is usually unsatisfactory, due to the usually limited face length that can be kept open and the soft nature of the country rock. When stope timbering is required on the face, handlashing to stope tracks 24 feet apart on dip is a most effective method. It is not uncommon for top spiling to be required on the face from timber stringer sets erected at 4-5 feet centres on dip. The waste overcut is packed back, the reef is lifted by pneumatic picks, and removed either by hand shovel to stope trucks or when the grade of ore is high into jute pockets for transport to surface. With wider reefs and stronger ground conditions, shaker shutes suspended from the timber sets have been used. These can be hand or pneumatically operated and are used for dips between 0^{o} and 10^{o}. Good supervision is required for effective operation of this type of equipment.

4(f) A resue method of stoping was used in the vertical reef in Rietfontein mine where the reef occurs in the basement granites with one sidewall decomposed for a distance of 2-4 feet. A reef drive connection is made on a payable stretch and is fully timber set. Overhand stoping then commences and the reef removed down double cribways 50 feet apart on strike. The soft sidewall is stoped by picking 4-6 feet up alongside the reef. This waste product is packed on the sets between the cribways. On completion of the waste cut cycle, the reef is blasted down on to flat slab lagging lain on the waste fill. The reef is blasted to within 2 feet of the advanced waste cut. The reef is removed by handlashing into wheelbarrows or by small portable 7½ H.P. air operated scraper units. A vertical back between levels of 150 feet is convenient. Cribways are double, one side for reef removal and the other side for services, travelling and for clearing hung up rock. Two-inch pipes are effective speaking tubes for communication between the level below and the working face. A full shrinkage stoping method is unsatisfactory as the soft sidewalls collapse at the withdrawal stage. Underhand stoping with loaded stulls is unsafe due to sidewall caving.

4(g) Normal 2⅛" hand held jackhammers are used with ⅞" hexagonal 46 inch tungsten carbide tipped drill steel, with a tip gauge of 44 m.m. There was an improvement of over 30% in drilling performance in hard dolomite with chert bands with the introduction of tungsten carbide steel, compared with detachable forged bits or forged steel. An average of 560 feet drilled per rod is obtained at a cost of 84 cents per 100 feet. Rubber collars have proved more effective than forged shanks and are cheaper. Air legs have replaced stopers in steep overhand workings. Pneumatic hand held pick machines weighing 15/20 lbs. are most effective in oxidised ground. These machines require little maintenance and their extensive use has resulted in a marked improvement in productivity.

4(h) With wide orebodies outcropping or occurring near surface the opencast method of mining can be highly productive and economical. Where the orebodies are massive the operation is mechanised to a high degree but where the ore occurs in a stockwork of leaders which require clear mining for grade control, limited mechanised equipment can only be used and hand loading is satisfactory. An

important consideration is the ratio of waste removed to ore produced, the actual ratio depends on the value of the ore.

4(h)(i) A detailed knowledge is required of the orebody before planning a waste stripping operation and siting the waste dumps. A diesel operated shovel loader and an electrically operated scraper have been used. The former has a high purchase cost and requires a number of self tipping trucks, depending on the length of tram to the dump site. This equipment is highly flexible and mining can be selective. A ½ cu.yard shovel handles 400-500 tons per shift at a cost of 50-75 cents per ton depending on the type of ground. A 60 H.P. scraper unit removes 150 tons per shift. This method although cheap in initial outlay can only operate in fairly soft ground and selective mining is difficult.

5. UNDERGROUND HAULAGE SYSTEMS

5(a) With mines operating near surface the broken ore tends to be sticky and is difficult to handle in gravity systems such as ore-passes. Various types of rope haulage systems for handling trucks loaded at the face have been found effective over long distances underground. They have a low cost of installation and maintenance. Diesel operated locomotives have proved most satisfactory underground when track gradients are suitable. They are cheaper both in installation and operating cost than electric battery locomotives.

5(b) Reversible Rope Haulages.

5(b)(i) Two types of reversible rope haulage systems have been used. The main and tail, using a winch at both ends, and the endless rope with a single reversible driving unit. Both employ a single track. The latter case has several advantages over the former. It is cheaper since it has only one driving unit. It can pick up or drop off trucks fitted with rope clamps, such as gooseneck jockeys, without stopping the system. The signalling requirements are far simpler since only one driver is required.

5(b)(ii) A 6,000 ft. reversible endless rope haulage easily deals with the output from 6 inclines feeding to it. Trucks fitted with jockey brackets are fed onto the rope and knocked off at the inclines as required. The process is reversed to haul back the fulls. The haulage system can be adapted to feed to a shaft at one or both ends of the haulage. The rope speed is 4 miles per hour. The diameter of the rope ¾ ins. and the 4 ft. diameter fleeting wheel is driven by a 60 H.P. motor. Tonnage handled is 240 tons per 8 hour shift. This type of haulage is suitable for an elongated ore body. A series of this type of haulage served a mine with a strike length of some 11,000 feet with the length of the orebody on dip averaging only 150 feet. The pitch of the orebody was 4^{o} against the load.

5(c) Endless Rope Haulage.

5(c)(i) This type of haulage is best for flatly dipping reefs where payability extends approximately equal distances on dip and strike. The haulage has no difficulty negotiating bends where a system of rollers guide the rope on the jockey brackets round the curves. A number of horned rollers are used on each bend to keep the rope in position on the remaining rollers. The track plan of the haulage

can be square, rectangular or in a figure eight.

5(d) Endless Rope Double Track

5(d)(i) This system has a high capacity and is installed where conditions permit of a double track. It is best suited for feeding from point to point such as from a collecting level to surface via a main adit. A haulage of this type has a capacity of 460 tons per 8 hour shift over a distance of 2,500 feet. Flat bottomed 12 cu.ft. cars are used with 30 lb. track at 18" gauge. The rope diameter is ¾" with a speed of 4 m.p.h.

5(e) Single Track Hoisting

5(e)(i) The commonest system used is the single track, single drum electric winch hauling from stopes on the herringbone system or a direct haul from one level to another.

5(e)(ii) A typical unit consists of a 30 H.P. electric motor geared to a drum giving a rope speed of 4 m.p.h. hauling up an incline of 7° to 10°. The length of haul is 500 feet with a rope diameter of ½ ins. and a rock load of 3 tons. An average performance of such a unit in a herringbone stope with turnouts at 40 ft. intervals is 42 tons per 8 hour shift. On a straight haul from one level to another the output is 160 tons per 8 hour shift.

5(f) FIGURE II gives the layout of a flat dipping mine using various types of haulages feeding to two vertical shafts. The mine produced 5,500 tons of reef per month and 4-5,000 tons of waste.

6. SURFACE HAULAGE SYSTEMS

6(a) The topography of the country, the distances involved, the tonnage to be handled and the capital available, are factors which determine the type of surface haulage system to be installed.

6(b) Animal Transport

6(b)(i) Mules have been extensively used for surface contour tramming over distances up to 1,200 feet. Relays of mules are used for longer trams. They are mainly used as feeders to mechanical haulages in areas where the tonnages involved do not justify much capital expenditure. The harness is a chest strap supported on saddles attached to draw chains on either side of the animal.

6(b)(ii) A typical mule haulage system is:- length of haul 6,000 feet operated by five spans of two mules in tandem, feeding to one another in each direction at stations 1,200 feet apart. The tonnage handled per shift is 200.

6(b)(iii) In isolated occurrences with very limited tonnages in mountainous country, pack mules have been used economically and effectively.

6(c) Mechanical Tractor Haulage

6(c)(i) A normal petrol driven farm tractor has been adapted to haul spans of 20 trucks over a tramming distance of 6,000 feet. The tractor wheels straddled the 18 inch gauge track with ample clearance. The distance travelled per shift is 22 miles for tonnage handled of 120. The cost per ton/mile is approximately 1 cent. This

type of haulage is suitable as a feeder system for handling medium tonnages from areas with low reserves. It is flexible and little capital is required.

6(d) Electric Tramways

6(d)(i) Overhead trolley locomotives are used for long hauls from areas where track gradients are light. The method is most suitable for collecting tonnages from outlying producing units where sufficient reserves have been proved to justify a fairly high capital expenditure. The locomotives used operate at 500 volts D.C. with a drawbar pull of 2,400 lbs. The tramming speed is 10 miles per hour with a span of 20 hoppers, each with a carrying capacity of 1.6 tons. The running cost including crews and maintenance is 10 cents per ton/mile.

6(d)(ii) Storage battery locos are used over shorter hauls from mines with more limited reserves. The capital cost of the loco is higher but the units are more flexible. This type of loco has a higher maintenance cost and a more limited carrying capacity.

6(e) Road Transport

6(e)(i) With the improvement in road construction over recent years and the working of a number of more isolated deposits, the use of road transport has been extended. The method is most flexible and can be used for limited tonnages from widespread areas or from steady producers well removed from the mill, where tonnages do not justify the erection of a separate reduction plant. A fleet of ten 8-ton Diesels hauled 5-6,000 tons per month over a distance of 13 miles to the central mill. The side-tipping arrangements on the lorries is operated by an overhead winch at the tipping point, thus reducing the purchase price of the vehicle. Heavy road gradients preclude the use of trailers. Elevation differences of over 2,000 feet between loading and delivery points have been encountered. For determining the best route for a haul, profiles of the alternative routes are plotted. An average operating cost per ton/mile is 6 cents.

6(f) Self Acting Gravity Planes

6(f)(i) This simple and cheap method of handling ore down hillsides has been extensively used and has proved most efficient. For inclinations less than 25^{0}, spans of cars or single units are used. For steeper gradients and higher tonnages, bottom dump skips can be used. The type of brakewheel depends on the load and distance of tram. For light loads, the fleeting wheel is mounted horizontally. This wheel and its brake path are cast together. Three turns of the rope round the fleeting wheel are sufficient to prevent brake slip for control of the descending loaded span. With larger loads, double drums are used with heavier brakeing arrangements. One system has proved effective over a distance of 1,500 feet with loads of 5 tons. The capacity is 200 tons per 8 hour shift. Erection, maintenance and operating costs are exceedingly low.

6(g) Aerial Gravity Haulages

6(g)(i) Where the countryside does not lend itself to the laying of tracks due to steepness and irregularities, this type of haulage has proved most reliable and cheap to operate. Two $1\frac{1}{2}$" diameter secondhand winding ropes spread 6 ft. apart are anchored top and bottom

of the slope, and serve as standing ropes. Buckets with a carrying capacity of ½-ton are underslung from a framework carrying the running pulleys. The hauling rope is ½" diameter and has three turns round the brake wheel. It is attached to the framework of the bucket. The performance on an aerial gravity plane with a rope span of 1,800 feet averaged 130 tons per shift with a top rope speed of 1,500 feet per minute. The bucket load is ½-ton.

6(h) Aerial Tramway

6(h)(i) This type of haulage is used for all transport in heavily dissected country where gradients are too heavy for road transport. The capital cost is usually high, requiring the establishment of reasonable reserves before construction. The system used is a bi-cable continuous tramway with fulls and empties travelling in opposite directions on two ⅝" diameter track cables. The capacity is 120 tons on two shifts with ½-ton buckets hauled by a ½" diameter traction rope. The length of the haul is 4,265 ft. with seven supporting towers. Maintenance costs tend to be high, with moderate running costs. The power requirement is usually low as there is a degree of counter-balancing of the full and empty buckets.

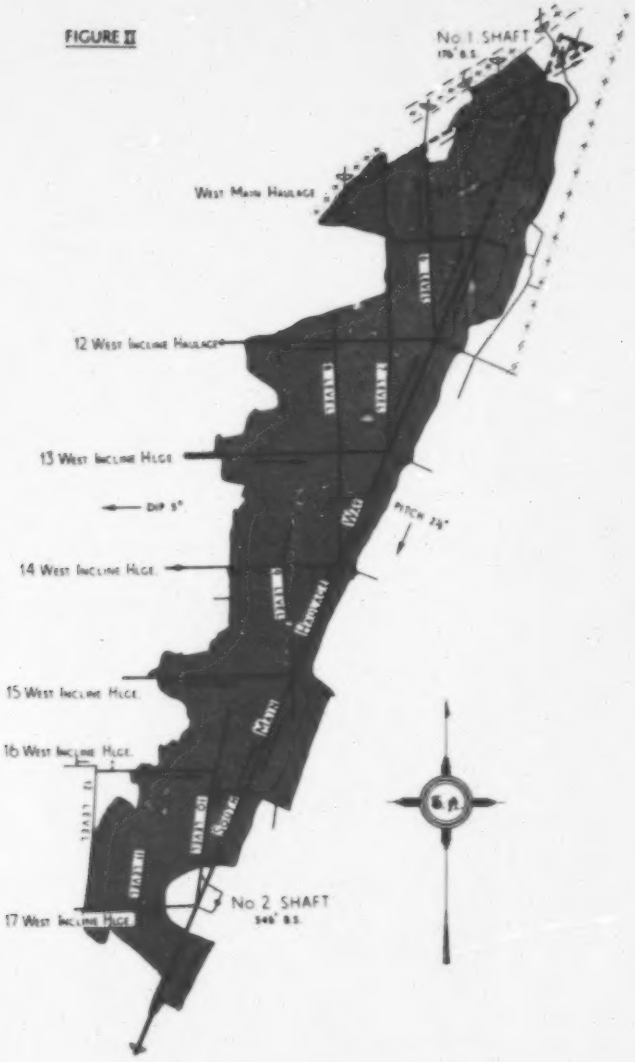
7. POWER GENERATION

7(a) An adequate and reliable power supply is essential for a mechanised mining operation. The type of power supply and size of unit are determined by local conditions, the life of the mine and capital available. A number of units have been assembled of which the largest station is a 1,800 A.W. hydro consisting of three double discharge turbines. In an area of fluctuating seasonal rainfall the necessity for supplementing units during the dry season reduces the advantage of the extremely low operating costs for hydro power. With improved mining prospects a 750 A.W. steam turbine was added. A comparison of the generating costs of the various units in operation is: hydro 0.14 cents/unit steam 0.8 cents, suction gas 2.3 cents and diesels 3.0 cents. All units are phased into a common transmission circuit.

8. CONCLUSION

8(a) The degree to which mechanisation can be economically introduced into a mining operation depends on many factors. The nature of the orebody and the percentage payability will determine the type of equipment which can best be employed and the amount of mechanisation which can be economically adopted. The rate at which a property is to be opened up and the required rate of production are also determining factors. Some details of the extent and size of an orebody and of possible reserves of payable tonnages are required before a mechanisation programme can be fully planned. Efficient utilisation of equipment depends on sound maintenance procedures, maximum operating time and a reliable and adequate power supply. The location of a mine and the regularity of supplies will determine the quantity and range of stocks to be carried. The type and supply of labour and the conditions of employment are also factors which must be considered. Much benefit can be derived from the application of work study to the planning and operation of a mechanisation programme. In small mining operations extensive mechanisation does not always produce the most economic results. Sound judgment is required for the introduction of mechanical equipment which however, when soundly applied, can greatly increase productivity and mining efficiency.

FIGURE II



TRANSVAAL GOLD MINING ESTATES LIMITED.

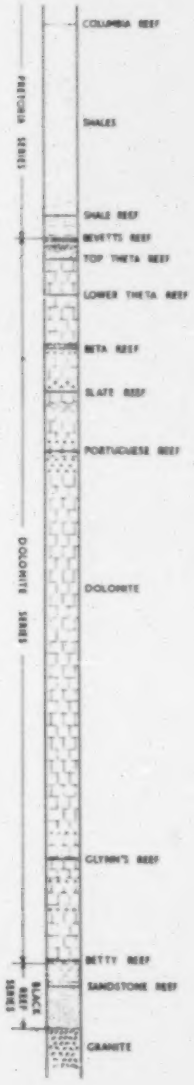
PLAN SHOWING LAYOUT OF UNDERGROUND WORKINGS AT VAALHOEK MINE

LEGEND

STOPED AREAS
REEF DRIVES
HAULAGES (DIVISIBLE ROPE, DOUBLE ROPE, SINGLE TRACK)
DYKES
WATERTIGHT DOORS

FIGURE I

COLUMNAR SECTION



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